The Study of the Spatial Coherence of Surface Waves by the Nonlinear Green-Naghdi Model in Deep Water

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LONG-TERM GOAL

The goal is to identify the role of nonlinear wave interaction in the spatial coherence of ocean waves within the MOB Program of ONR. For this purpose, a numerical tool based on the Green-Naghdi model will be developed to simulate short-crested irregular waves in deep water.

OBJECTIVES

The objectives are to develop the higher-level Green-Naghdi model, to provide oceanographers/ocean engineers with a new numerical, nonlinear wave model, and to simulate efficiently the fully-nonlinear interaction in short-crested random ocean surface waves. Emphasis will be placed on the optimization between accuracy and computational effort by adjusting the `Level' of the model.

APPROACH

The irrotational version of the GN model, or the IGN model (see Kim et al., 1998), will be used to model the nonlinear evolution of ocean waves. The accuracy of the model can be controlled by the 'Level' of the model, which can be defined as the number of interpolation functions used in the vertical direction. As the Level goes up, the model describes the physics more accurately, however, facing an unavoidable penalty of higher computational effort required. The Level will be chosen such that simulations can be performed with minimal effort and redundancy in accuracy. The optimized model will be discretized by pseudo-spectral method on the horizontal plane. For a given wave spectrum, the initial wave distribution will be seeded based on the linear theory. To reduce the distortion of the wave spectrum, which is due to the incompatibility between the initial conditions and the evolution model, 'nonlinearity switching' technique (see e.g., Bai et al. 1992) will be introduced. The data processing technique to capture the coherent structure of waves will be studied further during the current project. Dr. Jang Whan Kim, a Post Doctoral Fellow, will work on the development of the numerical model.

WORK COMPLETED

In the two month period since the project started, the validity of the new GN model has been tested using its finite-depth model. The convergence of the numerical solution to a known exact solution has been confirmed in case of progressive waves of permanent form. The nonlinear interaction in time domain is tested in a 2-D numerical wave flume. The wave decomposition phenomenon for waves passing over a submerged shelf is simulated. The numerical results of the new model agree well with the available experimental data, as well as the results from the existing GN model up to Level 2, which is the maximum level available in the application of the old model (see Ertekin and Becker, 1998; Ferrier et al. 1997).

RESULTS

The propagation of nonlinear waves over a shelf is simulated and compared with the experimental result of Ohyama et al. (1995). Figure 1 shows the time history of wave elevation at a wave gauge and over two periods. Convergence of the numerical solution can be observed when the Level of the IGN model is increased. The predicted wave elevation by Level 3 and 4 models show good agreement with the experimental data. For Level 1 and 2 results, comparisons were also made with the numerical results of Ferier et al. (1997), where the original GN model was used. In Level 1, the two models give identical results. In Level 2, the results were almost identical to each other. From these results, we built confidence on the accuracy of the new model as the extension of the original GN model.

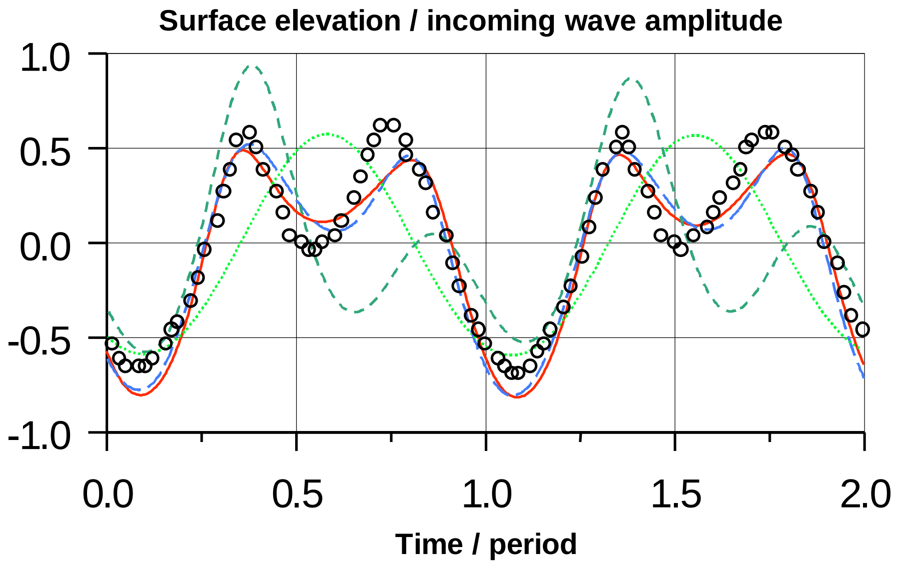

Figure 1. Computed versus experimentally measured free-surface elevations at a given point and as functions of time: ○ ○ ○, experimental result of Ohyama et al. (1995); , IGN Level 1; , IGN Level 2; , IGN Level 3; , IGN Level 4.

IMPACT/APPLICATION

A new numerical model for nonlinear evolution of deep-ocean waves will be developed. The new model will be able to provide the input for the wave environment that can be used in the design of Very Large Floating Structures (VLFS) such as the proposed Mobile Offshore Base (MOB).

TRANSITIONS

None

RELATED PROJECTS

None

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